OZONE EXPOSURE, UPTAKE, AND RESPONSE OF DIFFERENT-SIZED BLACK CHERRY TREES

Todd S. Fredericksen[1], John M. Skelly[1], Kim C. Steiner[1], and Thomas E. Kolb[2]

Abstract: Differences in exposure, uptake and relative sensitivity to ozone between seedling, sapling, and canopy black cherry (*Prunus serotina* Ehrh.) trees were characterized during two growing seasons in north central Pennsylvania. Open-grown trees of all sizes received a similar amount of ozone exposure. Seedlings had greater foliar ozone injury, expressed as adaxial stipple and early leaf senescence, than larger trees, which was correlated with their higher rates of stomatal conductance and greater rates of ozone uptake. The higher stomatal conductance and ozone uptake of seedlings was proportional to their higher (less negative) predawn xylem water potentials. Seedlings appeared to have some ability to compensate for injury because their free growth habit reduced exposure per unit leaf area compared to larger trees whose leaves were exposed to ozone throughout the entire growing season.

INTRODUCTION

Black cherry is a widespread deciduous tree species in eastern North America and is a highly-valuable commercial timber species in the Allegheny Mountains of Pennsylvania and West Virginia. However, black cherry also appears to be extremely sensitive to tropospheric ozone (Davis and Skelly 1992, Simini et al 1992). Ozone concentrations often reach high levels in this region during the growing season and may impact the growth of black cherry (Comrie 1994). One problem with determining the impact of ozone on large, forest-grown black cherry trees, however, is that most air pollution studies have used seedlings grown in field chambers or greenhouses (Reich 1987, Pye 1988). The objective of this study was to determine if differences in physiology and/or ozone exposure related to tree size may impact uptake of ozone and foliar injury response. More detailed results are presented by Fredericksen et al. (1995a, 1995b).

METHODS

The study site is located within the Moshannon State Forest in Clearfield County, PA within the Allegheny Plateau physiographic province. Open-grown seedlings, saplings, and 80-year-old canopy black cherry trees were identified for study during the 1993 and 1994 growing seasons. Saplings were located in a canopy gap in 1993 and in a larger forest opening in 1994. Seedlings were 1-2 year-old nursery transplants approximately 0.5-1.5 m in height. Saplings were 5-7 m and canopy trees were approximately 20 m tall. Data collected during each growing season included seasonal within-canopy ozone concentrations for each tree size, daily and seasonal patterns of leaf gas exchange, predawn xylem water potential, seasonal leaf area development, and foliar ozone injury expressed as percent adaxial stipple and early leaf senescence. Ozone uptake was calculated for each tree size class as the product of ozone exposure and stomatal conductance adjusted for differences in diffusivity between water vapor and ozone. All measurements were made within the upper crown of each tree size class.

[1]Research Associate, Environmental Resources Research Institute; Professor, Department of Plant Pathology; and Professor, School of Forest Resources, respectively, The Pennsylvania State University, University Park, PA, 16802.

[2]Assistant Professor, School of Forestry, Northern Arizona University, Flagstaff, AZ, 86011.

RESULTS AND DISCUSSION

7-hour average (0900-1600 EST) ozone concentrations were slightly higher during the 1994 growing season compared to 1993 (Table 1). Ozone concentrations were similar within the crowns of open-grown seedlings, saplings, and canopy trees, although sapling and canopy trees had lower ozone exposure than seedlings in 1993.

Ozone uptake rates tended to decrease with increasing tree size (Table 1). High seedling uptake rates were correlated with higher rates of stomatal conductance. The higher stomatal conductance and ozone uptake of seedlings may be explained by the higher (less negative) xylem water potentials of seedlings because seedlings have a shorter path length of water transport compared to larger trees, allowing for higher rates of stomatal conductance.

Table 1. Ozone exposure ($nl.l^{-1}$, 7-hour mean), stomatal conductance ($mol/m^2/s$), ozone uptake ($umol/m^2/hr$), predawn xylem water potential (-MPa), percentage adaxial ozone stipple (Sept. 1), and percentage early leaf abscission (Sept. 1) of seedling, sapling, and canopy black cherry trees during 1993 and 1994. Saplings sampled in 1993 were growing in a canopy gap. Saplings sampled in 1994 were open-grown. Standard errors of means are in parentheses.

Tree Size	Ozone Exposure	Stomatal Conductance	Ozone Uptake	Predawn Water Potential	% Ozone Stipple	% Early Leaf Abscission
Seedlings						
1993	40.3	0.23	29.6	0.12	0.6	6.9
	(0.51)	(0.01)	(1.22)	(0.01)	(0.1)	(2.3)
1994	48.0	0.50	58.1	0.12	43.8	30.45
	(0.51)	(0.02)	(0.79)	(0.02)	(3.5)	(10.6)
Saplings						
1993	42.2	0.16	19.6	0.22	0.2	5.2
	(0.48)	(0.01)	(0.35)	(0.01)	(0.01)	(1.7)
1994	48.5	0.40	48.6	0.18	12.5	3.8
	(0.51)	(0.02)	(0.74)	(0.02)	(1.2)	(2.0)
Canopy						
1993	46.3	0.18	16.1	0.46	0.1	6.9
	(0.55)	(0.01)	(0.37)	(0.04)	(0.01)	(2.6)
1994	48.8	0.28	33.8	0.36	19.1	4.4
	(0.53)	(.01)	(0.57)	(0.02)	(1.50)	(2.0)

Seedlings had larger amounts of foliar injury per unit ozone exposure than saplings or canopy trees during both growing seasons (Table 1). Incidence of foliar injury and leaf senescence per unit leaf area was generally low in 1993, but much greater in 1994. Seedlings had greater rates of early leaf senescence than larger trees during 1994. The higher amounts of ozone uptake and foliar injury symptoms during 1994 may be explained by a higher soil moisture content during 1994. Growing season rainfall totaled 74.5 cm during 1994 and 51.1 cm during 1993. Showman (1991) similarly observed that foliar injury symptoms were much higher during a wet year with than a drier year despite relatively higher ozone during the dry year.

During 1993, and to a lesser extent in 1994, ozone injury to older seedling leaves may have been partially compensated by the production of new uninjured leaves throughout the growing season. Early leaf abscission of

older, injured leaves and replacement with new leaves may allow for the maintenance of high rates of whole plant net photosynthesis. Canopy trees, exhibiting fixed growth, did not have this compensatory ability. Open-grown saplings exhibited some free growth, but canopy-gap saplings did not.

SUMMARY

Slight differences in ozone exposure were evident within the mature forest canopy and in forest openings. Seedlings had higher rates of ozone uptake and foliar ozone injury than saplings and canopy trees. Ozone uptake rates were positively related to stomatal conductance and xylem water potentials. Seedlings appeared to have some ability to compensate for foliar injury on older leaves by the production of new foliage throughout the growing season.

ACKNOWLEDGMENTS

This study was funded by the United States Environmental Protection Agency with additional support from the Pennsylvania Department of Environmental Resources, the U.S. Forest Service, Penelec GPU Corporation, and the Pennsylvania Conservation Corps.

LITERATURE CITED

Davis, D.D. and J.M. Skelly. 1992. Foliar sensitivity of eight eastern hardwood species to ozone. J. Air, Water, Soil Poll. 62:269-277.

Fredericksen, T.S., B.J. Joyce, J.M. Skelly, K.C. Steiner, T.E. Kolb, K.B. Kouterick, J.E. Savage and K.R. Snyder. 1995a. Physiology, morphology, and ozone uptake of seedlings, saplings, and canopy black cherry trees. Environ. Pollut. (in press).

Fredericksen, T.S., J.M. Skelly, K.C. Steiner, T.E. Kolb, and K.B. Kouterick. 1995b. Size-mediated foliar response to ozone in black cherry trees. Environ. Pollut. (in press).

Pye, J.M. 1988. Impact of ozone on the growth and yield of trees: A review. J. Env. Qual. 17:347-360.

Reich, P.B. 1987. Quantifying plant response to ozone: a unifying theory. Tree Physiol. 3:63-91.

Simini, M.J., J.M. Skelly, D.D. Davis, J.E. Savage, and A.C. Comrie. 1992. Sensitivity of four hardwood species to ambient ozone in northcentral Pennsylvania. Can. J. For. Res. 22:1789-1799.

Showman, R.F. 1991. A comparison of ozone injury to vegetation during moist and drought years. J. Air Waste Mgt. Assoc. 41:63-64.